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Accelerated Corrosion In Weathering Steel Bridges – An Update

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Abstract:

The paper describes the results of an inspection of three structures having box girders fabricated from weathering steel. Areas exhibiting accelerated corrosion were found inside the box sections of two of the structures where surface run-off had entered the box. Several examples of construction debris and vermin were observed.

Recommendations for the design of inspection hatches, for avoiding accelerated corrosion in new structures and for retrofitting existing structures are given.

Key Words: bridges, box girders, corrosion, de-icing chemicals, drainage, salt

Comments: This paper expands upon the contents of the report "Accelerated Corrosion in Weathering Steel Bridges", ME-84-03, by D.G. Manning.

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INTRODUCTION

An investigation of the condition of weathering or atmospheric corrosion resistant (ACR) steel bridges was undertaken in 1981 [1]. Numerous examples of accelerated corrosion were observed, especially on surfaces exposed to roadway drainage, and this resulted in some modifications to design details. The most extensive corrosion was found inside a trapezoidal box beam structure under municipal jurisdiction. The possibility of serious corrosion inside box beams fabricated from weathering steel led to the inspection in June, 1981, of the interior of three box beam structures which were not inspected internally in the 1981 survey. This brief report summarizes the results of those inspections and makes further recommendations for the design and retrofitting of ACR box beams.

Site 3-264 Rideau River Bridge at Kemptville, Highway 16

The structure consists of twin trapezoidal boxes continuous over five spans. It was built in 1973. Corrosion was observed at the ends of both beams and extended approximately 4 m from each end diaphragm as shown in Figures 1 and 2. The corrosion had resulted from moisture seeping through the copes and half-round openings in the end diaphragms. In the north beam there was also seepage between the deck and the diaphragm. This can be seen in Figure 2. The north beam was walked through from end to end. There were several bird nests (thought to be starlings) adjacent to the soffit ventilation holes where there was no drip sleeve, as shown in Figure 3. No bird nests were found adjacent to ventilation holes fitted with sleeves. Considerable litter was evident in the beam. The deck had been cast using wooden forms. Consequently, the soffit was easily inspected and found to be in excellent condition. Some of the formwork had not been removed, especially near the abutments (as shown in Figure 2). Four holes were left in the deck for formwork removal, and patched after construction of the remainder of the deck was complete. One of the forms used to construct the patches is shown in Figure 4. The access hatches were not hinged and consequently had to be removed. This was both awkward and hazardous.

Site 27-210 South Nation River Bridge, Highway 417 Near Casselman

There are twin bridges at the site, each consisting of twin trapezoidal boxes continuous over three spans. They were built in 1972. The beams were entered only at the west abutments. There was a dank odour and evidence of corrosion in all the beams. The corrosion was most advanced in the south beam of the north structure which is shown in Figures 5, 6, and 7. As was the case with Site 3-264, the corrosion was the result of run-off from the deck surface flowing down the end diaphragms from defective deck joint seals and entering the box through the copes and half-round openings in the end diaphragms. These openings were approximately 20 mm in diameter. A 480 mm diameter ventilation hole (visible in Figure 5) had been provided in each end diaphragm, but formwork covering the opening had not been removed. There was a small amount of leakage around the formwork. The corrosion was confined to approximately 5 m from the end diaphragm in all cases. Permanent steel forms were used for the deck over each beam. There was severe corrosion of the formwork (shown in Figure 8) near the end of the same beam illustrated in Figures 5 to 7.

This beam was walked through from end to end. The remainder of the beam was in good condition except that the corrosion near the east abutment was comparable to that at the west abutment. The access hatches were found to be well located and relatively easy to enter and exit.

Site 29-132 Madawaska River Bridge at Burnstown (County of Renfrew)

The structure was built in 1975 and consists of twin trapezoidal box beams continuous over three spans. Both beams were walked through from end to end. The south beam was in good condition throughout. There was some corrosion, which appeared to be the result of condensation, near the east abutment of the north beam. Although there was no free moisture at the time of inspection, there was evidence of dripping from the permanent steel forms and the cross bracing onto the bottom flange. The beams were constructed without vents.

There was no wetness associated with a 'tide-mark' found in one section of the north beam and it could have been present since the time of erection. Although the inspection hatches were located in the end diaphragms, there was negligible leakage because there appeared to be little leakage through the deck joints and the diaphragms were recessed about 0.6 m from the ends of the beams. Accelerated corrosion had occurred between the diaphragms and the east end of the beams because water ponded at these locations.

Discussion

The findings of these inspections confirm the findings of the previous study [1]. It is worth reiterating that most of the steelwork was found to be in good condition, but the observations also emphasize the potential for accelerated corrosion inside box beams fabricated from ACR steel. The worst examples of corrosion occur within approximately 5 m of the ends and are associated with leakage of surface run-off through openings in the end diaphragm. It is therefore imperative that end diaphragms be watertight.

The amount of construction debris, formwork, and nesting material observed inside the box beams was greater than had been anticipated. The construction debris and formwork needs to be removed for reasons of safety and the ability to inspect surfaces not now visible. It also decreases the possibility of fires being lit by unauthorized personnel who might enter the beam. The nesting material is, perhaps, of greater concern because if it becomes wet it will retain moisture in contact with the steel which could result in severe localized corrosion. The Burnstown bridge indicated the consequences of not providing adequate ventilation in box beams and the challenge to the designer is clearly to provide sufficient ventilation while sealing the box against the ingress of moisture. This can best be done by installing vents in the soffit. The provision of a short sleeve appears adequate to keep out birds. While there was no evidence of insects inside the three structures inspected, it would seem to be prudent also to fit the sleeve with an insect screen. Since welding practices dictate that the copes cannot be eliminated, a sealant needs to be installed at the time of construction.

While it has been reported that corrosion inside box beams has been confined to leakage adjacent to deck joints and deck drains (see Reference 1, Site 10-172), it should be noted that none of the bridges inspected to date have exhibited leakage through cracks in the deck slab. As far as is known, all box beam structures in Ontario have a waterproofing membrane on the bridge deck. As these structures age, the possibility of moisture entering the boxes through the deck slab cannot be discounted. This caution also applies to jurisdictions having box beam structures with exposed concrete decks.

A wide variety of inspection hatches were encountered in this and the earlier study. Some hatches were found to be very convenient to enter and exit; others were almost impossible to open and access was difficult. These observations enabled the desirable features of an inspection hatch to be identified and led to the formulation of specific recommendations.

Although the corrosion illustrated in some of the figures appears to be very severe, the loss of section is very small. Provided that debris and corrosion deposits are removed and that the source of the leakage is eliminated, it is anticipated that these structures will perform satisfactorily, given normal maintenance practices in future years.

RECOMMENDATIONS

A. New Construction

1/ End diaphragms must be sealed against ingress of moisture. Copes shall be cleaned with a wire brush and sealed with silicone sealant.

2/ Vents shall be provided in the soffit at not greater than 7 m centres. The vent shall include a tube fitted with an insect screen. A suitable detail is given in Figure 9.

3/ All construction debris and formwork shall be removed from boxes before the bridge is accepted.

4/ Hatches shall be provided in the webs such that they are accessible for inspection but not for the general public. The opening shall be fitted with hand-holds, the door hinged and bolted, and sealed with a gasket. A suitable detail is shown in Figure 10.

B. Existing Bridges

1/ Where corrosion is taking place in existing bridges, the corrosion products should be removed to SSPC "Surface Preparation No. 3 - Power Tool Cleaning," and all openings through which moisture can enter should be sealed. Large apertures should be sealed by custom-fabricated steel; small openings by silicone sealant. All debris should be removed, including construction debris, vermin nests, and the accumulated particles created by the wire brushing of corrosion products.

2/ Vents shall be provided in the soffits of any structures built without vents.

3/ Vents not fitted with tubes shall be so equipped.

REFERENCE

[1] Manning, D.G., "Accelerated Corrosion in Weathering Steel Bridges," Proc. of Canadian Structural Engineering Conference, Canadian Steel Construction Council, March 1984.

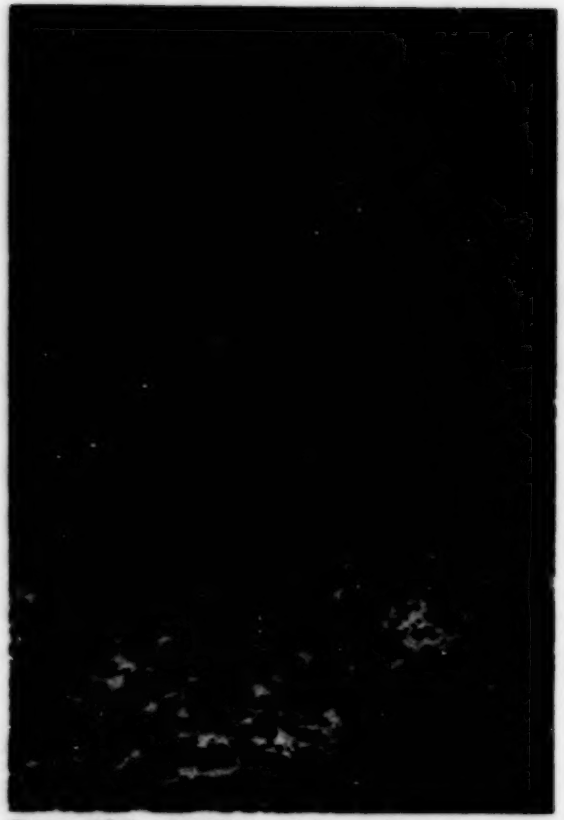


Figure 2/ Site 3-284 North Beam East Abutment

Note the formwork which has not been removed and the seepage at the top and bottom of the end diaphragm.

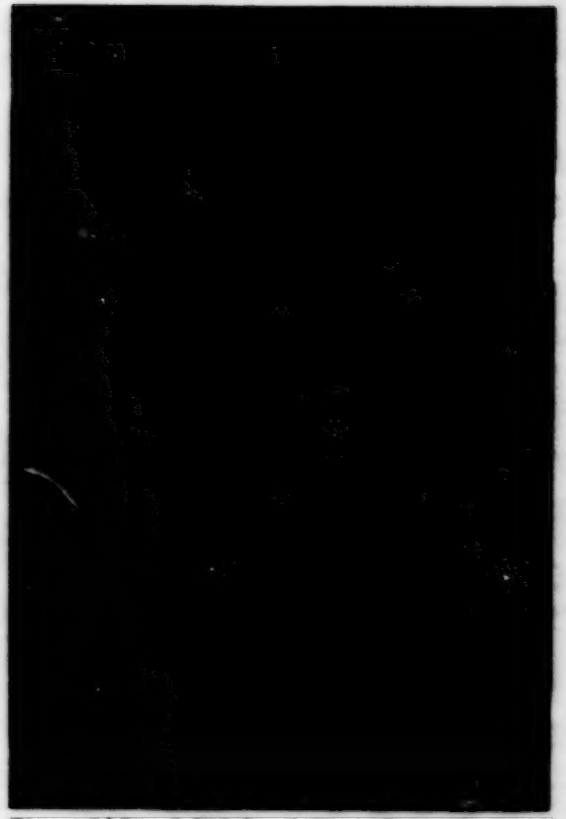


Figure 1/ Site 3-284 South Beam East Abutment

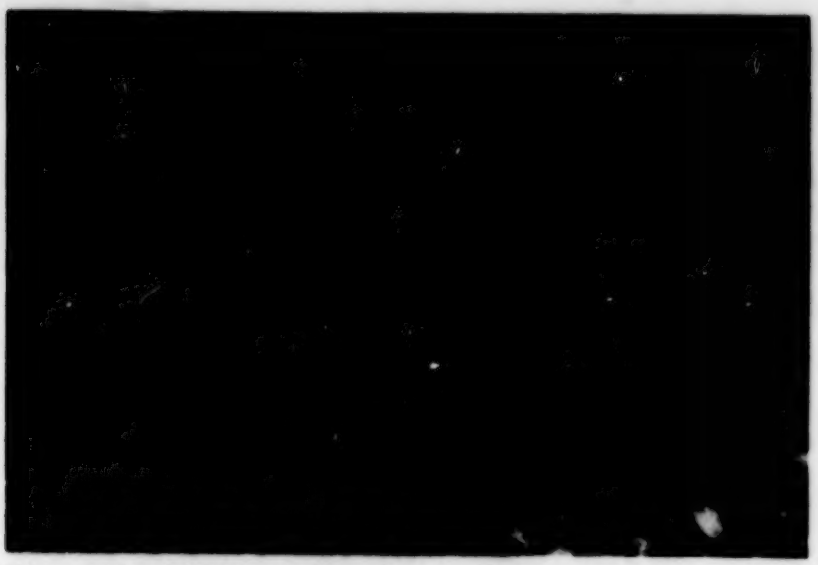


Figure 3/ Site 3-284 North Beam Bottom Flange

Note the bird nest between the stiffeners and adjacent to the vent in the soffit. The vent has no sleeve.

Figure 4/ Site 3-284 North Beam

Formwork used to patch a construction access in the deck was left inside the beam.

Figure 5/ Site 27-210 North Structure South Beam West Abutment

Note the extensive corrosion of the soffit, web and diaphragm and the 480 mm diameter vent which was sealed with timber.

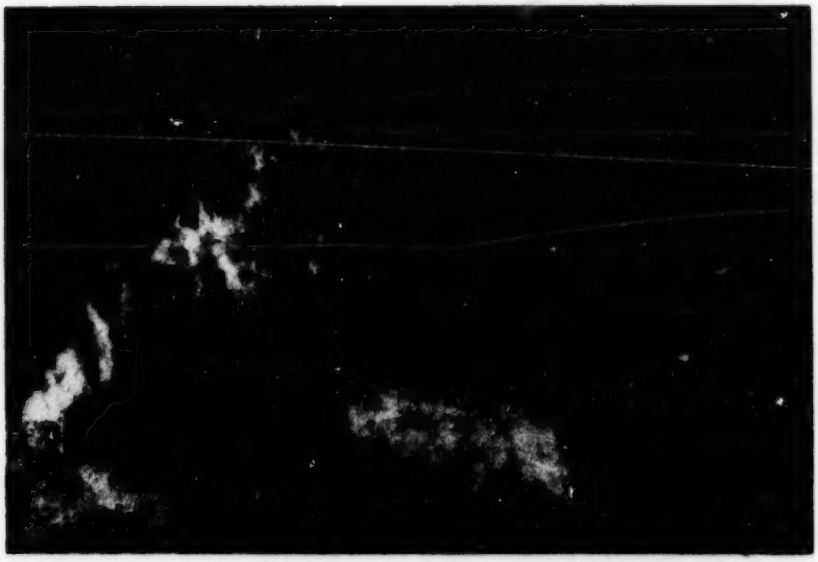


Figure 6/ Site 27-210 North Structure South Beam West Abutment

Close-up of extensive corrosion visible on the web in Figure 5.

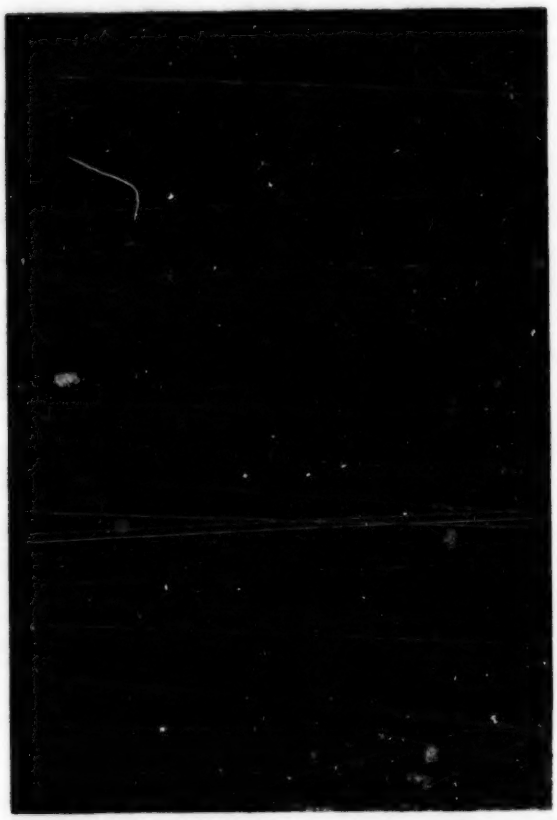


Figure 7/ Site 27-210 North Structure South Beam West Abutment

Close-up of web stiffener visible in Figure 5.

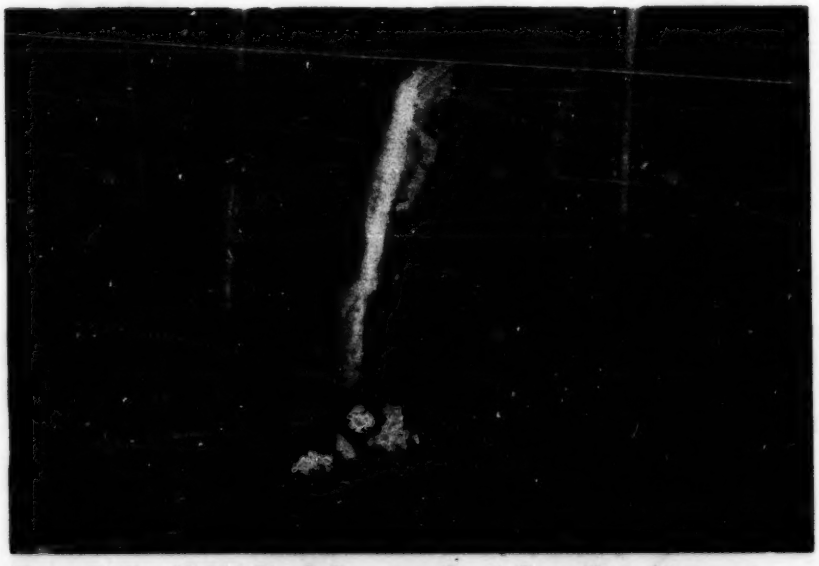


Figure 8/ Site 27-210 North Structure South Beam West Abutment

Corrosion of permanent steel deck forms adjacent to deck joint.

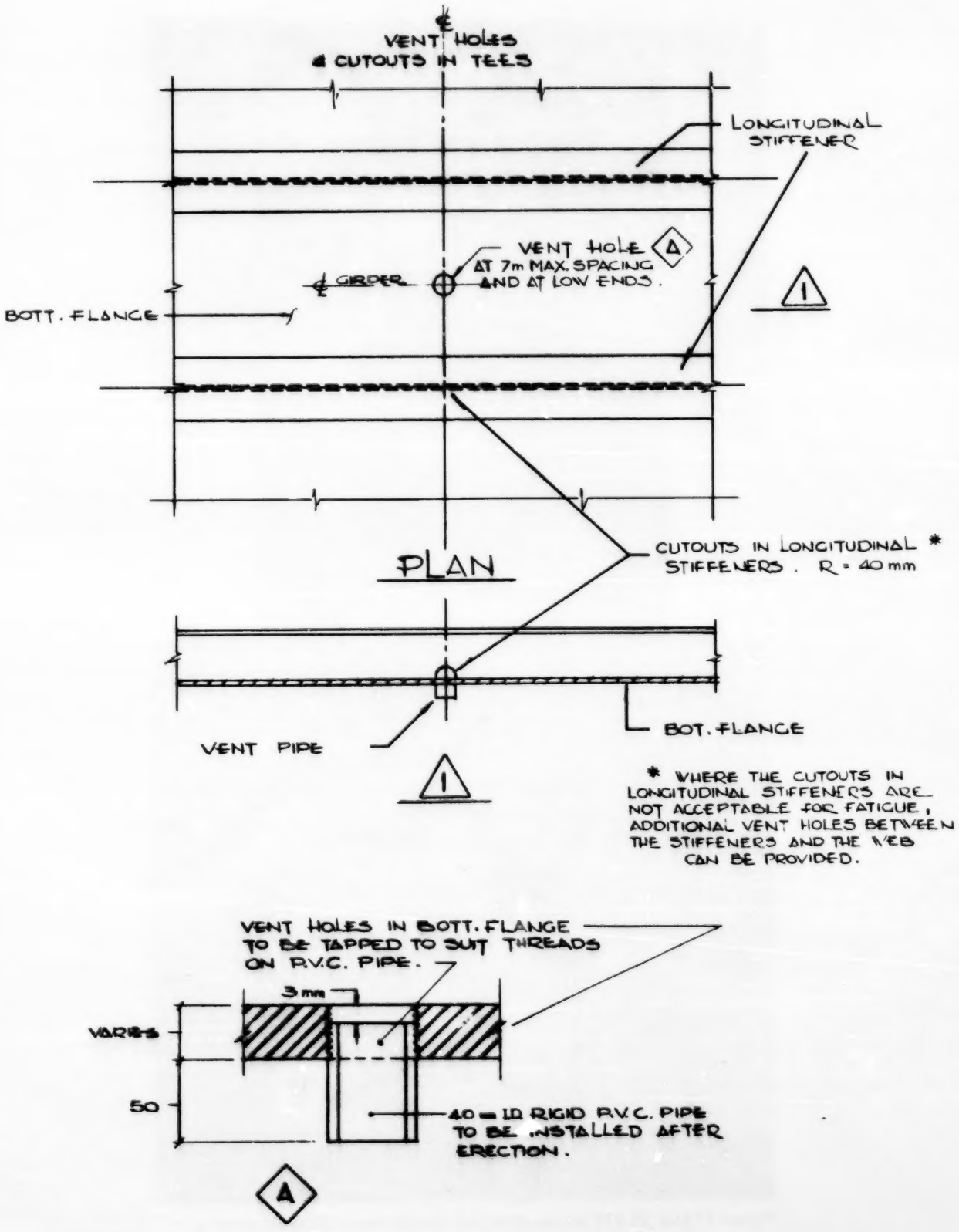
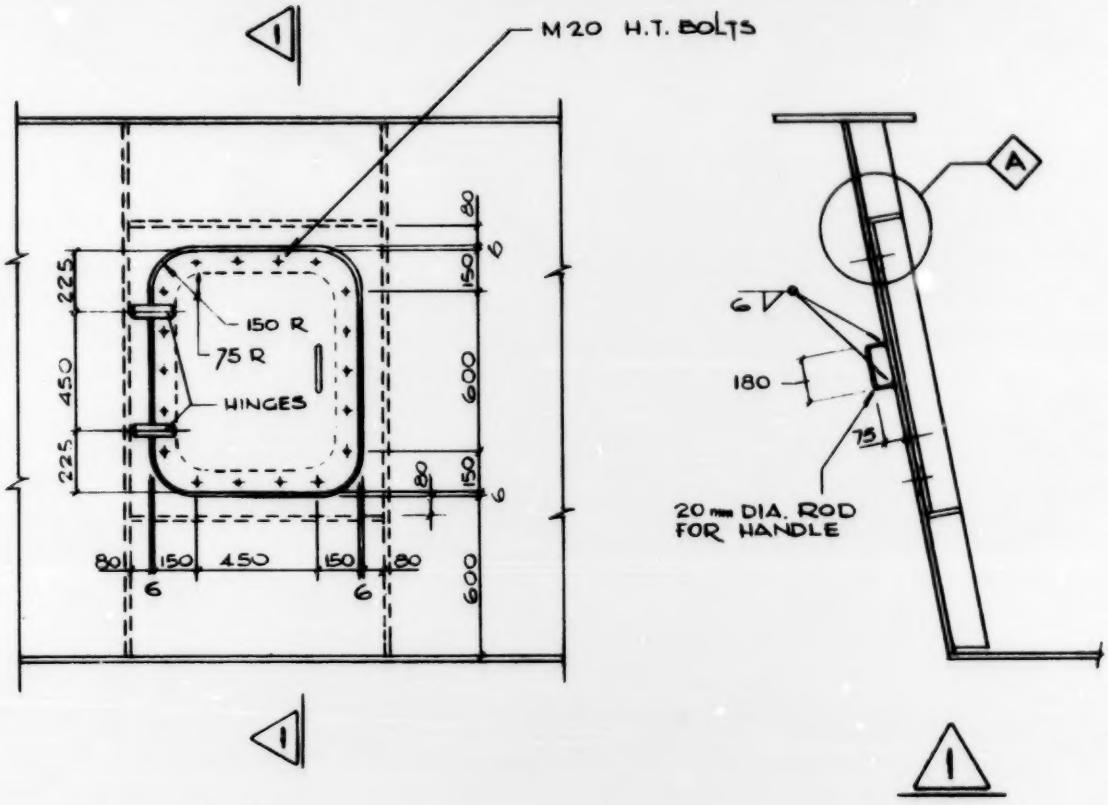

℄ VENT HOLES & CUTOUTS IN TEES
LONGITUDINAL STIFFENER
VENT HOLE Δ AT 7m MAX. SPACING AND AT LOW ENDS.
℄ GIRDER
BOTT. FLANGE
1
PLAN
CUTOUTS IN LONGITUDINAL * STIFFENERS. R = 40 mm
VENT PIPE
BOT. FLANGE
1
* WHERE THE CUTOUTS IN LONGITUDINAL STIFFENERS ARE NOT ACCEPTABLE FOR FATIGUE, ADDITIONAL VENT HOLES BETWEEN THE STIFFENERS AND THE WEB CAN BE PROVIDED.
VENT HOLES IN BOTT. FLANGE TO BE TAPPED TO SUIT THREADS ON P.V.C. PIPE.
3 mm
VARIES
50
40 mm I.D. RIGID P.V.C. PIPE TO BE INSTALLED AFTER ERECTION.
Δ

Figure 9/ Vent Detail



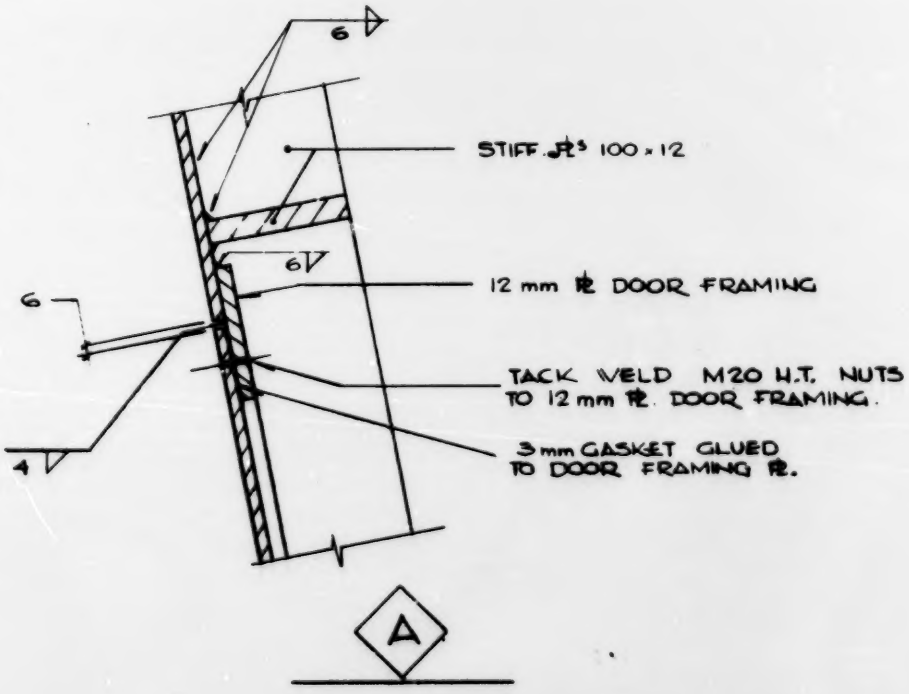


Figure 10/ Access Hatch Detail